Observational Study

Comparison of the Outcomes of Percutaneous Endoscopic Interlaminar Lumbar Discectomy and Open Lumbar Microdiscectomy at the L5-S1 Level

Sung Kyu Song, MD[1], Seong Son, MD, PhD[1], Sun Woo Choi, BS[2], and Hwi Kyung Kim, BS[2]

From: [1]Department of Neurosurgery, Gil Medical Center, Gachon University College of Medicine, Incheon, South Korea; [2]Gachon University College of Medicine, Incheon, South Korea

Address Correspondence:
Seong Son, MD, PhD
#24, 74th St, Namdongdaero
Namdong-Gu, Incheon, 405-220,
South Korea
E-mail:
sonseong@gilhospital.com

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Background: Although many studies have compared full endoscopic spine surgery and open spine surgery, few have compared the outcomes of percutaneous endoscopic interlaminar lumbar discectomy (PEILD) and open lumbar microdiscectomy (OLM) at the L5-S1 level.

Objectives: We compared the clinical, surgical, and radiological outcomes of patients with disc herniation at the L5-S1 level who underwent either PEILD, or OLM, performed by a single surgeon with novice-level proficiency.

Study Design: Observational, retrospective matched cohort design.

Setting: An analysis of clinical data was performed at a single center, collected from September 2012 to August 2016.

Methods: The study enrolled 56 patients who underwent discectomy at the L5-S1 level, with a minimum one-year follow-up. Patients were allocated to 2 groups: a PEILD group (n = 27; September 2014 to August 2016), or an OLM group (n = 29; September 2012 to August 2014). Clinical, surgical, and radiological outcomes were retrospectively evaluated.

Results: Baseline characteristics including age, gender, past medical history, body mass index, preoperative symptom, and preoperative radiological findings did not differ significantly between the groups. Further, overall clinical outcomes including back and leg pain; surgical outcomes including blood loss, complication rate, and recurrence rate; and radiological outcomes including degree of decompression, disc height, and sagittal alignment were not different significantly between the 2 groups.

However, the PEILD group showed significant advantages including lower immediate postoperative back pain (mean 1.44 [95% confidence interval (CI), 1.16-1.72] versus 2.41 [95% CI, 2.14-2.69], $P < 0.001$), favorable immediate postoperative Odom's criteria (excellent 57.14% versus 24.14%, $P = 0.025$), shorter operation time (mean 63.89 ±17.99 minutes versus 109.66 ±31.42 minutes, $P < 0.001$), shorter hospital stay (3.15 [95% CI, 2.21-4.09] days versus 5.72 [95% CI, 3.29-8.16] days, $P < 0.001$), and rapid return to work (15.67 [95% CI, 12.64-18.69] days versus 24.31 [95% CI ,19.97-28.65] days, $P = 0.001$).

Limitation: Due to its retrospective nature, it was not possible to control for all variations. Moreover, the number of patients in the final cohort was relatively small.

Conclusions: Our findings indicate that the PEILD group achieved better perioperative outcomes despite no significant intergroup difference in mid-term clinical and radiological outcomes.

Key words: Complication, discectomy, full endoscopic surgery, lumbar disc herniation, lumbar spine, microscopic surgery, outcome, recurrence

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The full endoscopic interlaminar approach via single portal using a small-diameter working channel, also known as percutaneous endoscopic interlaminar discectomy (PEILD), is a safe, effective, minimally invasive surgery for treating disc herniation at the L5-S1 level (1,2). The classic transforaminal endoscopic approach is limited at the L5-S1 level due to anatomic barriers, such as a high iliac crest and narrow intervertebral foramen, or surgical situations, such as axillar type or migrated disc herniation (1). To overcome these limitations, PEILD was introduced in the mid-2000s and has been used as an effective full endoscopic surgery for lumbar disc herniation (LDH) at the L5-S1 level (1,2). Several reports have demonstrated the surgical feasibility and a favorable clinical outcome of PEILD, which has been used as a standard full endoscopic surgery at the L5-S1 level (3-6).

On the other hand, open lumbar microdiscectomy (OLM) remains as the standard surgical procedure worldwide, with proven safety and effectiveness for LDH (7-12). However, recently, many comparative studies have emphasized that, there is no significant difference in clinical results between full endoscopic surgery and OLM, or that full endoscopic surgery is superior to OLM in some aspects (13-21). Accordingly, although OLM has been the gold standard surgery for LDH, full endoscopic surgery is increasingly being accepted as the alternative approach (22-24). Further, a comparative study should also be conducted in terms of disc herniation at the L5-S1 level, especially PEILD versus OLM. However, only a few studies have compared the outcomes of PEILD and OLM at the L5-S1 level (9).

We compared the clinical, radiological, and surgical outcomes of PEILD and OLM performed by a single surgeon with similar novice-level proficiency in a single center. To the best of our knowledge, this is the first study to compare the outcomes of PEILD and OLM for LDH at the L5-S1 level based on a single surgeon and similar surgical skill proficiency.

Methods

Surgical Indication and Patient Population

The study was approved by the Institutional Review Board of our institute (GFIRB2020-105). The Institutional Review Board waived the informed consent from patient and all patient data were anonymized.

A single surgeon in a single institute performed the spinal surgeries beginning in September 2012, after fellowship training of 1.5 years. The surgeon performed only OLM in patients with disc herniation at the L5-S1 level until August 2014. From September 2014 on, the surgeon performed PEILD in patients with soft disc herniation at the L5-S1 level, after a 4-week fellowship and several cadaveric training programs for full endoscopic spine surgery. As a result, the surgeon had similar novice-level proficiency for both OLM and PEILD during the time studied.

The indications for lumbar discectomy surgery were as follows: 1) persistent low back pain and radiating leg pain despite conservative treatment for at least 6 weeks, 2) severe pain affecting activities of daily living or paresis with motor grade ≤ 3, regardless of the duration of conservative treatment.

A retrospective study was performed for all patients who underwent OLM (between September 2012 and August 2014) or PEILD (between September 2014 and August 2016). To minimize the influence of multilevel or bilateral surgery on outcomes, we identified patients who underwent single-level unilateral discectomy at the L5-S1 level.

During the study period, 40 and 31 patients underwent single-level, unilateral OLM and PEILD, respectively. Therefore, the average term between 2 cases was not significantly different between the 2 groups (0.60 month in the OLM group versus 0.77 month in the PEILD group).

To avoid selection bias due to different characteristics of disc herniation between the 2 groups, we set up several inclusion and exclusion criteria. The study inclusion criteria were as follows: 1) soft disc herniation on preoperative magnetic resonance imaging (MRI) or computed tomography (CT), 2) disc herniation within the spinal canal or lateral recess, and 3) follow-up for at least one year. Those who met any of the following criteria were excluded: 1) hard (calcified) disc herniation on MRI or CT, 2) foraminal or extraforaminal disc herniation, 3) upward migrated disc fragmentation, 4) history of previous surgery on the lumbar spine, 5) instability or spondylolisthesis, or 6) an inability to complete the pre- and post-operative questionnaires or insufficient medical records.

After the exclusion of 15 patients, the remaining 56 were enrolled in the final study cohort. The final cohort was divided into a PEILD group (n = 27) and an OLM group (n = 29) (Fig. 1).

Operative Technique

After the induction of general anesthesia, all

patients were placed in the prone position with decreased abdominal pressure.

In the PEILD group, a paramedian 0.5 cm skin incision was made 0.5-1.0 cm far from the midline. After insertion of the obturator, a working cannula and endoscope (Vertebris System, Richard Wolf, Knittlingen, Germany or Joimax System, Joimax, Irvine, CA, USA) were inserted. Under endoscopic guidance with continuous irrigation, the ligamentum flavum was punctured by partial removal or split, after bone work in some cases. The ruptured disc material was removed, disc space was evacuated if necessary, and annuloplasty was performed using radiofrequency (Elliquence Int, Hewlett, NY, USA). Finally, the wound was closed using a single point subcutaneous suture and skin tape.

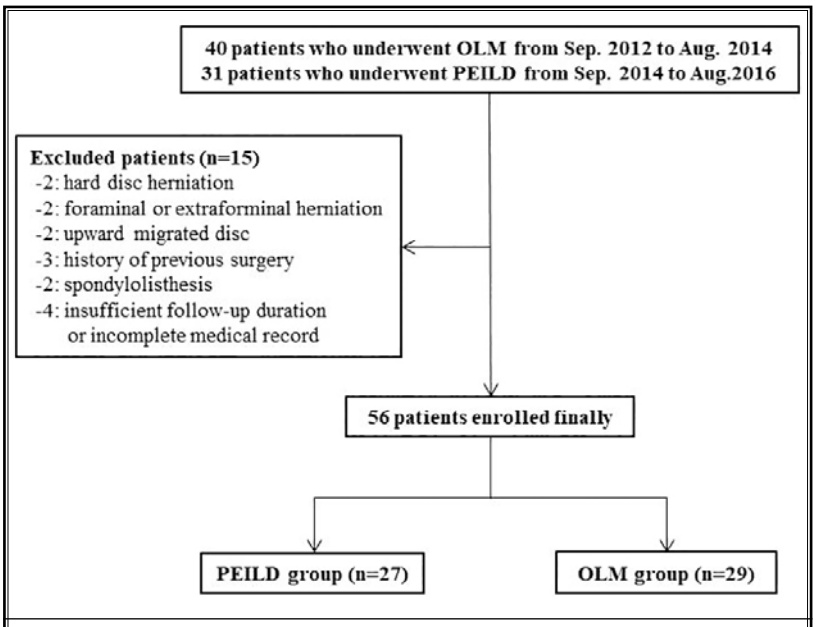

Fig. 1. *Patient selection process*
OLM, open lumbar discectomy; PEILD, percutaneous endoscopic interlaminar lumbar discectomy.

In the OLM group, a midline 2.5-4.0 cm skin incision was made followed by periosteal dissection and the application of a Caspar-type retractor. Under microscopic guidance, after partial laminectomy and removal of the ligamentum flavum, removal of ruptured disc with or without disc space evacuation was performed. Finally, the wound was closed using layer-by-layer suturing, after drain insertion if necessary.

In both groups, equipment used, bone work, and intervertebral disc evacuation were determined depending on preoperative planning and/or intraoperative findings.

Outcome Evaluation

Collected data included follow-up clinical survey and x-ray data obtained from the outpatient clinic regularly.

Demographic data and baseline characteristics, including age, gender, occupation, smoking status, alcohol consumption, body mass index (BMI), previous history of nerve block, trauma history, preoperative symptom duration, and presence of weakness were analyzed.

Clinical outcomes were assessed using visual analog scale (VAS) scores for low back pain and leg pain. Data were collected preoperatively and at each follow-up visit (one week, one month, and one year). Patient satisfaction was surveyed using Odom's criteria at each follow-up visit.

Surgical outcomes were evaluated using operation time; procedure during surgery, including bone work, disc space evacuation, and drain insertion; intraoperative blood loss; surgical failure, including conversion to OLM during PEILD; surgical complications, such as durotomy, neurologic deterioration, or surgical site infection; morbidity, such as pneumonia, cardiac problem, or deep vein thrombosis; hospital stay; time to return-to-work; and recurrence rate for additional procedure. Operation time was evaluated in categories: preparation time to operation including anesthesia and drape, operation time from skin incision to wound closure, and recovery time. Intraoperative blood loss was evaluated indirectly using pre- and post-operative hemoglobin levels. Recurrence rate and the additional procedures after surgery, including revision surgery and nerve block during follow-up, were investigated.

Lumbar MRI was performed preoperatively, and the Pfirrrmann grade for disc degeneration (25), rupture side (right or left), rupture type (by disc level or migration), and ruptured disc volume were recorded. Ruptured disc volume was determined as (transverse diameter × depth × height of disc herniation × 1/2) of the ruptured disc fragment on MRI. We performed immediate postoperative MRI in all patients to confirm the

decompression of the nerve root. Remnant ruptured disc volume was evaluated using the same method.

Plain and dynamic radiographies were performed preoperatively and at one year postoperatively, to evaluate the radiological outcomes. Disc height was measured as an average of anterior, middle, and posterior disc height and corrected using the ratio of disc height to the anteroposterior diameter of the L5 vertebral body to overcome any variations of x-ray magnification. Segmental angle and range of motion at the surgery level, and total lumbar lordosis were measured using Cobb's method to assess the change in lumbar alignment.

Statistical Analysis

Data management and statistical analysis were performed using SPSS version 23.0 (SPSS Inc., IBM Corporation, Armonk, NY). Pearson's Chi square test, one-way analysis of variance (ANOVA), Friedman's test (a nonparametric multiple comparison test), independent t-test, paired samples t-test, and non-parametric Mann-Whitney U test were used according to the characteristics of the factors. The results were expressed as mean ± standard deviation or mean and 95% CI, depending on whether the data were normally distributed. Statistical significance was accepted for P values < 0.05.

Results

Demographic Data and Baseline Characteristics

Overall, 56 patients (31 men, 25 women) were included, with a mean age of 42.09 ±12.86 years, BMI of 24.00 ± 3.32, and symptom of 84.0 (95% CI, 49.18-118.82) days.

No significant intergroup difference was observed in demographic data. There was also no difference in baseline symptom-related or radiological characteristics on preoperative MRI (Table 1).

Clinical Outcome

Preoperative back pain VAS scores were not significantly different between the 2 groups and decreased progressively during follow-up in both groups (P < 0.001, Friedman, ANOVA test). However, back pain VAS scores decreased more significantly in the PEILD group immediately after surgery, although the declines at 6 months and one year were not significantly different between the 2 groups (Fig. 2). In other words, back pain VAS scores were more favorable in the PEILD group than in the OLM group at one week postoperatively (mean 1.44 [95% CI, 1.17-1.72] in the PEILD group versus 2.41 [95% CI, 2.14-2.69] in the OLM group, P < 0.001, nonparametric Mann-Whitney U test), whereas there was no difference at 6 months or one year postoperatively (Table 2).

Preoperative leg pain VAS scores were not significantly different between the 2 groups (mean 6.48 [95% CI, 5.84-6.98] in the PEILD group versus 6.41 [95% CI, 5.84-6.98] in the OLM group, P = 0.913, nonparametric Mann-Whitney U test), and decreased dramatically after surgery and tended to keep decreasing during follow-up in both groups (P < 0.001, Friedman, ANOVA test). The decreases in leg pain VAS scores were not significantly different between 2 groups (Fig. 3). In other words, the leg pain VAS scores did not differ significantly between the groups during all follow-up visits (Table 2).

According to Odom's criteria, patient satisfaction was favorable in both groups and significantly better in the PEILD group than in the OLM group at one week postoperatively (Excellent in 19 patients [59.3%] in the PEILD group versus 7 patients [24.1%] in the OLM group, P = 0.025, Pearson's Chi square test). However, patient satisfaction at 6 months and one year did not differ between the groups (Table 2).

Surgical Outcomes

Among the parameters, preparation time before surgery and recovery time from anesthesia after surgery were not different between the 2 groups. However, operation time, from skin incision to wound closure, was significantly shorter in the PEILD group than in the OLM group (63.89 ± 17.99 minutes in the PEILD group versus 78.03 ± 19.01 minutes in the OLM group, P = 0.006, independent t-test). Further, total operation time, that is, the sum of preparation, operation, and recovery times, was shorter in the PEILD group than in the OLM group (141.22 ± 29.17 minutes in the PEILD group versus 159.41 ± 25.11 minutes in the OLM group, P = 0.015, independent t-test) (Table 3).

Among the parameters related to surgical procedure, disc space evacuation and pre- and postoperative hemoglobin levels indicating intraoperative blood loss were not different between the 2 groups. However, bone work (14.8% in the PEILD group versus 93.1% in the OLM group, P < 0.001, Pearson's Chi square test) and drain insertion (0% in the PEILD group versus 48.3% in the OLM group, P < 0.001, Pearson's Chi square test) were more common in the OLM group than in the PEILD group (Table 3).

Fortunately, there were no cases of failure, including conversion to OLM during PEILD, in either group.

Table 1. *Baseline demographic data, clinical characteristics, and radiological characteristics on preoperative magnetic resonance imaging.*

	PEILD (n = 27)	OLM (n = 29)	*P* value
Age	42.85 ± 14.84	41.38 ± 10.92	0.673*
Gender			0.602†
Male	16	15	
Female	11	14	
Occupation			0.617†
White collar	12	13	
Blue collar	8	6	
Other	7	10	
Smoking	7	9	0.771†
Packs-year	3.13 (95% CI, 0.83-5.43)	4.55 (95% CI, 0.76-8.34)	0.719‡
Alcohol	14	10	0.280†
Height (cm)	167.69 ± 9.40	167.90 ± 9.72	0.937*
Weight (kg)	65.67 ± 9.48	69.83 ± 14.57	0.215*
Body mass index (kg/m^2)	23.35±2.92	24.61±3.60	0.161*
Symptom duration (days)	89.70 (95% CI, 41.54-137.86)	78.69 (95% CI, 25.74-131.64)	0.987‡
Previous nerve block	12	13	0.977†
Trauma	2	1	0.511†
Weakness	8	5	0.273†
Pfirrmann grade			0.596†
III	20	18	
IV	6	10	
V	1	1	
Side			0.586†
Right	12	15	
Left	15	14	
Type of ruptured disc			0.643†
Migrated	7	6	
Subligamentous	20	23	
Ruptured disc size (mm^3)	611.37 ± 298.63	547.92 ± 441.70	0.563*

CI, confidence interval; OLM, open lumbar microdiscectomy; PEILD, percutaneous endoscopic interalaminar lumbar discectomy
*Independent t-test
†Pearson's Chi square test
‡Nonparametric Mann-Whitney U test

There were no cases of perioperative morbidity related to the procedure, such as a cardiopulmonary problem or deep vein thrombosis (Table 3).

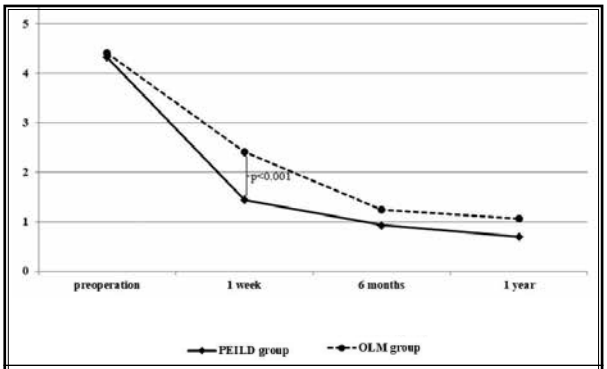

Fig. 2. *Back pain visual analogue scale scores of the two groups (*Nonparametric Mann-Whitney U test). OLM, open lumbar discectomy; PEILD, percutaneous endoscopic interlaminar lumbar discectomy.*

Complication rate was not different between the 2 groups. In the PEILD group, surgical complications occurred in 2 patients (incidental durotomy, 7.4%) during surgery. Conversely, in the OLM group, surgical complications occurred in 2 patients (6.9%), including one case of incidental durotomy during surgery and one case of transient voiding difficulty after surgery. However, there were no severe complications, such as permanent neurologic deficit or surgical site infection, after the procedure in either group.

Recurrence rate, requirement of additional nerve block, and revision surgery rate were not different between the 2 groups. In the PEILD group, 2 patients (7.4%) experienced recurrence of disc herniation and underwent revision surgery (one patient at 1.3 months after surgery and one patient at 5 months after surgery), and one patient underwent an additional nerve block for symptom control at 4 months after surgery due to recurrent leg pain. In the OLM group, 3 patients (10.3%) experienced recurrence of disc herniation and underwent revision surgery (2 patients within 10 days postoperatively and one patient at one month after surgery), with no requirement of additional nerve block (Table 3).

As expected, the hospital stay (mean 3.15 [95% CI, 2.21-4.09] days in the PEILD group versus 5.72 [95% CI, 3.29-8.16] days in the OLM group, $P < 0.001$, nonparametric Mann-Whitney U test) and time to return-to-work (mean 15.67 days [95% CI, 12.64-18.69] in the PEILD group versus 24.31 days [95% CI, 19.97-28.65] in the OLM group, $P = 0.001$, nonparametric Mann-Whitney U test) were significantly shorter in the PEILD group (Table 3).

Table 2. *Clinical outcomes*.

	PEILD (n = 27)	OLM (n = 29)	*P* value
VAS back			
Preoperative	4.33 (95% CI, 2.53-6.13)	4.41 (95% CI, 3.85-4.98)	0.934*
1 week	1.44 (95% CI, 1.17-1.72)	2.41 (95% CI, 2.14-2.69)	< 0.001*
6 months	0.93 (95% CI, 0.47-1.38)	1.24 (95% CI, 0.84-1.64)	0.180*
1 year	0.70 (95% CI, 0.40-1.01)	1.07 (95% CI, 0.75-1.39)	0.098*
Friedman ANOVA test			< 0.001†
ΔPreoperative-1 week	2.89 (95% CI, 2.30-3.77)	2.00 (95% CI, 1.37-2.63)	< 0.001‡
Δ1 week - 6 months	0.51 (95% CI, 0.75-0.62)	1.17 (95% CI, 0.68-1.66)	0.048‡
Δ6 months - 1 year	0.23(95% CI, -0.11-1.00)	0.17 (95% CI, -0.15-0.70)	0.427‡
VAS leg			
Preoperative	6.48 (95% CI, 5.67-7.29)	6.41(95% CI, 5.84-6.98)	0.913*
1 week	1.74 (95% CI, 1.35-2.13)	1.83 (95% CI, 1.54-2.12)	0.965*
6 months	1.30 (95% CI, 0.46-2.13)	1.28 (95% CI, 0.81-1.74)	0.303*
1 year	0.74 (95% CI, 0.36-1.11)	1.07 (95% CI, 0.70-1.43)	0.173*
Friedman ANOVA test			< 0.001†
ΔPreoperative-1 week	4.74 (95% CI, 3.99-5.48)	4.38 (95% CI, 3.73-4.93)	0.119‡
Δ1 week - 6 months	0.44 (95% CI, -0.53-1.42)	0.59 (95% CI, 0.16-1.01)	0.940‡
Δ6 months - 1 year	0.56 (95% CI, 0.00-1.11)	0.21 (95% CI, 0.00-0.45)	0.327‡
Odom's criteria (1 week)			0.025§
Excellent	16	7	
Good	10	21	
Fair	1	1	
Poor	0	0	
Odom's criteria (6 months)			0.525§
Excellent	19	18	
Good	6	10	
Fair	2	1	
Poor	0	0	
Odom's criteria (1 year)			0.547§
Excellent	20	19	
Good	7	9	
Fair	0	1	
Poor	0	0	

ANOVA, analysis of variance; CI, confidence interval; OLM, open lumbar microdiscectomy; PEILD, percutaneous endoscopic interalaminar lumbar discectomy; VAS; Visual analog scale
*Nonparametric Mann-Whitney U test, †paired samples Friedman ANOVA, ‡paired samples t-test, §Pearson's Chi square test

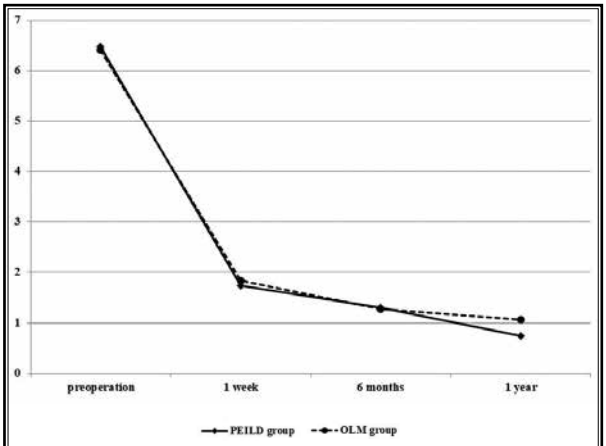

Fig. 3. *Leg pain visual analogue scale scores of both two groups. OLM, open lumbar discectomy; PEILD, percutaneous endoscopic interlaminar lumbar discectomy.*

Radiological Outcome

None of the radiological findings, including remnant ruptured disc volume, disc height ratio to vertebral body, segmental angle at surgery level, range of motion at surgery level, and total lumbar lordosis, differed significantly between the groups at pre-operation and at one year after surgery. On the other hand, the disc height ratio to vertebral body was significantly decreased in both groups (from 0.38 ± 0.10 to 0.36 ± 0.10 in the PEILD group, $P = 014$, and from 0.39 ± 0.08 to 0.37 ± 0.14 in the OLM group, $P = 0.030$, paired t-test) (Table 4).

Discussion

OLM is a classical surgery with sufficient supporting evidence published since the late 1970s and is known to be a standard surgical technique for LDH (7,12). On the other hand, PEILD is a full endoscopic spine surgery for disc herniation at the L5-S1 level and has been popular worldwide as an alternative, minimally invasive technique to OLM since the mid-2000s (23). Many studies have reported the efficacy and safety of PEILD at the L5-S1 level as well as other levels (1,4-6,26). However, few organized studies have compared the clinical outcomes of PEILD and OLM at the L5-S1 level.

In this study, all surgeries were performed by one surgeon in a single center, which helped maintain the quality of follow-up and exclude variability introduced by multiple surgeons. This single surgeon had performed OLM at the L5-S1 level since September 2012 and PEILD for soft disc herniation in the spinal canal or lateral recess since September 2014. There-

Table 3. Surgical outcomes.

	PEILD (n = 27)	OLM (n = 29)	*P* value
Preparation time (min)	36.48 (95% CI, 30.38-42.59)	35.17 (95% CI, 32.19-38.16)	0.596*
Operation time (min)	63.89±17.99	78.03±19.01	0.006†
Recovery time (min)	40.48 (95% CI, 31.09-49.87)	46.21 (95% CI, 42.28-50.13)	0.518*
Total operation time (min)	141.22±29.17	159.41±25.11	0.015†
Bone work	4 (14.8%)	27 (93.1%)	< 0.001‡
Disc space evacuation	23 (85.2%)	24 (82.8%)	0.805‡
Drain insertion	0	14 (48.3%)	< 0.001‡
Preoperative hemoglobin (g/dL)	14.03±1.47	14.30±1.33	0.500†
Postoperative hemoglobin (g/dL)	13.78±1.72	13.79±1.44	0.978†
Fail	0	0	Not available
Perioperative morbidity	0	0	Not available
Complication	2 (7.4%)	2 (6.9%)	0.596‡
Recurrence	2 (7.4%)	3 (10.3%)	0.941‡
Revision surgery	2 (7.4%)	2 (6.9%)	0.700‡
Additional nerve block	3	0	0.296‡
Hospital stay (days)	3.15 (95% CI, 2.21-4.09)	5.72 (95% CI, 3.29-8.16)	<0.001*
Time to return-to-work (days)	15.67 (95% CI, 12.64-18.69)	24.31 (95% CI, 19.97-28.65)	0.001*

*Nonparametric Mann-Whitney U test, †Independent t-test, ‡Pearson's Chi square test

Table 4. *Radiological outcomes.*

	PEILD (n = 27)	OLM (n = 29)	P Value
Remnant ruptured disc size (mm^3)	82.26 ± 44.78	61.23 ± 34.59	0.315*
Disc height ratio to vertebral body			
Preoperative	0.38 ± 0.10	0.39 ± 0.08	0.917*
1 year	0.36 ± 0.10	0.37 ± 0.14	0.907*
ΔPreoperative - 1year	0.02 (95% CI, 0.01-0.04)	0.02 (95% CI, 0.01-0.04)	0.970†
Segmental angle, surgery level (°)			
Preoperative	10.89 ± 5.49	8.26 ± 5.02	0.357*
1 year	10.50 ± 4.9	9.81 ± 5.92	0.775*
Range of motion, surgery level (°)			
Preoperative	7.01 ± 6.49	5.08 ± 4.44	0.548*
1 year	6.76 ± 4.83	4.79 ± 2.96	0.300*
Total lumbar lordosis (°)			†
Preoperative	30.73 ± 13.65	23.41 ± 12.74	0.305*
1 year	30.76 ± 11.80	28.20 ± 12.48	0.683*

CI, confidence interval; OLM, open lumbar microdiscectomy; PEILD, percutaneous endoscopic interalaminar lumbar discectomy
*Independent t-test, †Paired t-test

fore, surgical proficiency was similar novice-level stage in both groups during the study period. The inclusion criterion for patients enrolled in the final cohort was soft disc herniation in the spinal canal or lateral recess. We excluded patients with calcified lesions, upward migration, or foraminal/extraforaminal disc herniation to standardize the disc herniation characteristics. We also only investigated the data of patients who completed a minimum of one year of follow-up. This approach helped minimize various biases between the 2 groups to provide the most objective data.

According to our results, the long-term clinical outcomes, including improvement in back or leg pain and patient satisfaction, did not differ significantly between the 2 groups. However, immediate postoperative back pain and patient satisfaction at one week after surgery were more favorable in the PEILD group than in the OLM group. A small wound, sized 0.5 cm in the PEILD group versus 2.5-4.0 cm in the OLM group, and minimized muscle or soft tissue injury might be attributable for these differences in immediate postoperative clinical outcomes.

Mean operation time was significantly shorter in the PEILD group than in the OLM group (63.89 ± 17.99 versus 78.03 ± 19.01 minutes). In the OLM group, additional surgical procedures, including layer by layer open and closure, frequent bone work of laminotomy, and more common drain insertion might result in longer operation time than in the PEILD group.

Mean hospital stay and time to return-to-work were significantly shorter in the PEILD group than in the OLM group. These findings demonstrate that full endoscopic spine surgery is superior to classic microsurgery in terms of preservation of anatomical structure around surgical wound and rapid recovery after surgery.

Full endoscopic surgery is considerably different from conventional microsurgery because of the different anatomic view and equipment used. The obstacles to perform PEILD at the L5-S1 level include different

access method via percutaneous small one port, unfamiliarity to a endoscopic system, difficulty to reach interlaminar space, use of a narrow and magnified 2-dimensional endoscopic view, the presence of a vague or obscured view due to epidural bleeding, fear of dura tearing and neural injury, or uncertainty of successful decompression and disc space evacuation (6,27,28). Also, the surgical indications of the 2 surgical techniques are somewhat different, that is the indications of PEILD are narrower than those of OLM (1). For example, hard disc with calcification, upward migration of disc, and foraminal/extraforaminal disc herniation are limited to PEILD. Because of previous mentioned reasons, issues of concern for the surgeon in performing PEILD include surgical failure or conversion to microsurgery, the steep learning curve, complications during the novice stage, and recurrence rate in contrast to OLM (29).

However, fortunately, there were no cases of surgical failure or conversion to open surgery in this study. Further, there was no significant intergroup difference in the frequency of disc space evacuation and volume of remnant ruptured disc volume, suggesting a similar degree of nerve decompression and surgical efficacy between the 2 groups. Moreover, according to our findings, the complication rate in the PEILD group was reasonable as 7.4% while that in the OLM group was 6.9%. Furthermore, the recurrence rate (7.4% in the PEILD group versus 10.3% in the OLM group) and additional procedure rate including revision surgery and additional nerve block (11.3% in the PEILD group versus 10.3% in the OLM group) was not different between the groups. These findings support the fact that, with sufficient training and proper patient selection, surgeons can confirm ruptured or migrated lesion, remove pathology, and evacuate the disc space safely under the endoscopic view as well as under the microscopic view (6,30).

Limitations

This study has some limitations. Due to its retrospective nature, it was impossible to control for all confounding factors. Nevertheless, we tried to minimize errors by confounding variables associated with the results. Other limitations of the study were the small sample size and short follow-up duration. Despite these limitations, this study was the first to compare the clinical outcomes of PEILD and OLM at the L5-S1 level in the similar novice stage of surgeon. However, further studies with a large number of patients or a prospective design is mandatory to validate our results. Also, the difference of the learning curves and associated clinical outcomes of the 2 surgical techniques should be evaluated.

Conclusion

Our findings suggest that surgical efficacy and safety, in terms of nerve decompression and complication/recurrence rate, and outcomes after one year after surgery, did not differ significantly between the 2 groups. However, PEILD has several advantages over OLM as follows: 1) diminished surgery-related back pain and favorable immediate postoperative patient satisfaction due to the small wound and minimized soft tissue injury; 2) shorter operation time, hospital stay, and rapid return-to-work due to surgical techniques that omit the procedure and preservation of anatomical structure around surgical wound.

Author Contributions

Dr. S Son had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Dr. S Son designed the study protocol. Dr. S Son and Dr. SK Song managed the literature searches and summaries of previous related work and wrote the first draft of the manuscript. B.S. SW Choi and B.S. HK Kim supported the data acquisition and collecting. Dr. S Son provided revision for intellectual content and final approval of the manuscript.

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